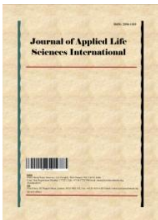

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Heavy Metals Concentration in Mango (*Mangifera indica* L.) Grown around Some Gold Mining Areas of Zamfara State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author NOSU designed the study and wrote the methodology. Author GBB performed the statistical analysis and wrote the first draft of the manuscript while both authors managed the literature searches and read and approved the final manuscript.

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ABSTRACT

Aims: This study was aimed at determining the concentration of heavy metals (Pb, Cd, Fe and Au) in mango plant parts (roots, stem barks, leaves and fruits) from two gold mining areas (Maraba and Duke) and the control (Kadauri) in Zamfara State, Nigeria for establishment of a baseline data for these metals and determining the suitability of the mango fruit for consumption.
Study Design: Analytical study design was applied in a stratified manner for the research.
Place and Duration of Study: The study was carried out in the environmental technology laboratory, National Research Institute for Chemical Technology (NARICT), Zaria, Nigeria between March and August 2019.
Methodology: A cumulative total of 96 samples of plant parts (roots, stem barks, leaves and fruits) were collected and analysed for Lead, Cadmium, Iron and Gold using Atomic Absorption Spectrophotometer (AAS) after digestion with a mixture of 20 ml HNO_3 and 8 ml $HClO_4$.
Results: The results obtained for the mean metal concentrations were; most abundant, Pb (62.07 ±

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54.09 mg/kg) in mango roots from Duke and the least abundant, Cd (0.52 ± 0.44 mg/kg) in fruits from Kadauri. All the metals had very high (> 0.5) translocation factors indicating fast movement from the roots to the shoots while the mean values of these metals in the fruits were found to be above the WHO and FAO maximum permissible limits which shows high level of contamination as a result of gold mining activities. Metals generally occurred in the order: Pb>Fe> Au > Cd and they differed across sampling stations with the mining areas having significantly (P<0.05) higher values than the control.

Conclusion: Heavy metals concentration in mango plant was found to be generally higher than the permissible limits hence the fruits are considered unsuitable for human consumption.

Keywords: Heavy metals; Mangifera indica L.; concentration; gold mining.

1. INTRODUCTION

Heavy metals are metals or metalloids that are persistent in all parts of the environment, generally have densities above 5 g/cm^3 and cannot be easily degraded or destroyed [1]. They include transition metals, actinides, lanthanides as well as the metalloids arsenic and antimony. Some of these heavy metals such as copper, cobalt, iron, manganese, molybdenum and zinc are essential for proper functioning of biological systems and are required in trace amounts, the excess of which can be detrimental. Non essential heavy metals of great concern include arsenic, cadmium, lead and mercury, they form part of the World Health Organization's list of ten chemicals of major public health concern [2]. Unlike organic contaminants which are oxidized to carbon (IV) oxide by microbial action, most heavy metals do not undergo microbial or chemical degradation [3], and their total concentration in the environment persists for a long time after their introduction [4]. Changes in their chemical forms (speciation) and bioavailability are however possible [5].

Gold mining and processing entails breaking the ground surface to excavate the ore, crushing the ore and then using water and/or other chemicals such as cyanide and mercury to concentrate the gold through sluicing, panning, floating and leaching. This employs the use of local tools, heavy equipments that use petrol or gasoline, and sometimes explosives such as dynamite [6]. Mining processes lead to metals being released from their stable form into the environment and removal of large quantities of overburden waste materials that are continuously dispersed through erosion, wind action and effluent draining the waste into arable land, surface and ground waters, polluting air, soil, vegetation, changing or destroying aquatic habitats, affecting agricultural lands, and causing health problems to humans [7,8].

Mango (*Mangifera indica* L.) is one of the most widely cultivated and popular fruits in the tropics and subtropics, and represents the fifth most cultivated fruit in the world, with 13.6 million tons of fruit produced in Africa alone during the year 2009 [9]. The plant is widely cultivated in Nigeria for fruit, fodder, fuel wood and other uses [10]. Mango fruits contain high concentrations of phytochemicals such as gallic acid, monogalloyl glucosides, gallotannins, flavonol glycosides and benzophenol derivatives which are unique to the plant [11,12]. Patches of mango plantations are found around the gold mining areas of Zamfara State, Nigeria.

This study was aimed at determining the concentration of heavy metals (Pb, Cd, Fe and Au) in mango plant parts (roots, stem barks, leaves and fruits) from the gold mining areas of Zamfara State, Nigeria and establishing a baseline data for these metals. The concentrations of heavy metals in mango fruits were compared with accepted safety limits, while there were also comparisons among gold mining sites in the area. This provides a basis for guiding further activities and preventing the exposure of humans through monitoring and control of the mining activities.

2. MATERIALS AND METHODS

2.1 The Study Area

Zamfara State of Nigeria is located between latitude 12°10'N and 12°167'N, and longitude 06°15'E and 06°250'E, it has a total area of 39,762 square kilometers, a warm tropical climate with average temperature rising up to 38°C and a wide variety of crops including patches of perennial tree plants are grown [13].

Samples were collected from two gold mining areas, namely Kwali (05°45.49'E–11°59.66'N) and Duke (06°19.56'E–12°21.45'N) together with a control site; Kadauri (06°08.71'E–12°13.56'N) about 20 km away from the mining areas.

2.2 Sample Collection

Samples of mango roots, stem barks, leaves and fruits from each of the mining sites and the control were collected monthly for a period of six months making a cumulative total of 96 samples.

Mango plant root samples at a depth of 10–15 cm together with the stem bark, leaves and fruit samples were collected using clean acid–washed stainless knife which was washed after each sampling to avoid cross–contamination according to [14,15].

2.3 Analysis of Samples

All glasswares used in the analysis of samples were washed using liquid soap, rinsed with distilled water and soaked overnight in 10% HNO_3 according to [16].

The samples were dried at room temperature, crushed with clean laboratory mill and sieved through 500 um to obtain fine particles. Two grammes of the particles were placed into 250 ml beaker, a mixture of 20 ml HNO_3 and 8 ml $HClO_4$ was used to digest the sample on a hot plate to a final volume of 5 ml. The digest was allowed to cool and drops of deionised water added to make it up to 100 ml. It was then analysed using Flame Atomic Absorption Spectrophotometer.

2.4 Statistical Tests

Analysis of variance (ANOVA) was used to determine whether significant difference exist among the values of different heavy metals across the two mining areas and the control site.

3. RESULTS

3.1 Heavy Metals Concentration in Mango Plant Roots

Mango roots had the hierarchical occurrence of metals as; Pb > Fe > Au > Cd with Pb and Cd having values of 62.07 ± 54.09 mg/kg in Duke and 1.39 ± 1.37 mg/kg in Kadauri respectively. Mean levels of metals in mango roots across sampling stations are shown in Table 1.

3.2 Heavy Metals Concentration in Mango Stem Barks

Mango stem samples in the study area had Pb (68.82 ± 36.13 mg/kg) as the highest metal concentration and Cd (0.93 ± 0.57 mg/kg) as the lowest while the order of occurrence was Pb > Fe > Au > Cd. Mean levels of metals in mango stem barks across sampling stations are shown in Table 2.

3.3 Heavy Metals Concentration in Mango Leaves

Pb and Cd with concentrations of 45.36 ± 35.04 mg/kg and 0,77 ± 0.78 mg /kg were the highest and lowest occurring metals in Mango leaves with the order Pb > Fe> Au> Cd.

3.4 Heavy Metals Concentration in Mango Fruits

The highest occurring metal in mango fruits was Fe (24.86 ± 21.22 mg/kg) while Cd (0.52 ± 0.44) was the lowest. The metals occurred in the order: Fe > Pb >Au >Cd.

3.5 Average Heavy Metals Concentration in Mango Plant Parts

The highest mean metal concentration throughout the period of study was Pb (46.48 mg/kg) in mango root and the lowest was Cd (2.08 mg/kg) in the leaves. The metals occurred in the order Pb > Fe > Au > Cd. The distribution of metals in mango plant parts during the study is shown in Fig. 1.

3.6 Metal Translocation Factors in Mango Plant

Fe had the highest translocation factor of 1.0 while Pb had the least, 0.70. Table 5 shows the distribution of metal translocation factors in mango plant during the study.

Table 1. Distribution of heavy metals in mango roots across the sampling stations

Metals	Maraba	Duke	Kadauri	F–value	Sig. value	P–test	Inference
Pb	57.58 ± 48.25	62.07 ± 54.09	19.80 ± 19.59	2.21	0.01	*P* <0.05	Diff. sig.
Cd	1.74 ± 2.87	4.91 ± 6.88	1.39 ± 1.37	1.02	0.01	*P* < 0.05	Diff. sig.
Fe	38.74 ± 31.00	37.38 ± 30.53	18.57 ± 11.56	0.99	0.04	*P* <0.05	Diff. sig.
Au	18.57 ± 7.29	18.72 ± 6.17	16.05 ± 3.79	2.12	0.08	*P*>0.05	Not sig.

Table 2. Distribution of heavy metals in mango stem barks across the sampling stations

Metals	Maraba	Duke	Kadauri	F–value	Sig. value	P–test	Inference
Pb	68.82 ± 36.13	54.04 ± 30.81	15.68 ± 5.64	3.51	0.03	*P* < 0.05	Sig. Diff.
Cd	1.67 ± 1.54	4.27 ± 4.46	0.93 ± 0.57	1.70	0.04	*P* <0.05	Sig. Diff.
Fe	45.17 ± 32.43	43.66 ± 33.59	21.78 ± 11.46	1.02	0.02	*P* <0.05	Sig. Diff.
Au	19.92 ± 14.67	18.53 ± 6.64	14.45 ± 5.98	2.31	0.04	*P*<0.05	Sig. Diff.

Table 3. Distribution of heavy metals in mango leaves across the sampling stations

Metals	Maraba	Duke	Kadauri	F–value	Sig. value	P–test	Inference
Pb	45.36 ± 35.04	33.93 ± 24.79	9.94 ± 4.29	2.66	0.02	P < 0.05	Sig. diff.
Cd	1.64 ± 2.29	3.83 ± 5.17	0.77 ± 0.78	0.89	0.04	P <0.05	Sig. diff.
Fe	32.85 ± 29.75	34.92 ± 31.27	14.07 ± 7.74	1.05	0.03	P <0.05	Sig. diff.
Au	19.58 ± 11.83	18.06 ± 8.26	13.83 ± 3.92	3.94	0.008	P <0.05	Sig. diff.

Table 4. Distribution of heavy metals in mango fruits across the sampling stations

Metals	Maraba	Duke	Kadauri	F–value	Sig. value	P–test	Inference	WHO limit [24]	FAO limit [25]
Pb	24.86 ± 21.22	27.00 ± 19.25	11.87 ± 2.55	1.24	0.04	*P*<0.05	Sig. Diff.	0.01	0.01
Cd	1.79 ± 1.97	4.66 ± 5.82	0.52 ± 0.44	0.84	0.03	*P*<0.05	Sig. Diff.	0.01	0.10
Fe	29.38 ± 20.16	42.22 ± 20.66	23.10 ± 11.99	0.69	0.04	*P*<0.05	Sig. Diff.	0.80	
Au	16.89 ± 4.84	20.41 ± 7.12	15.28 ± 4.89	3.41	0.016	*P*<0.05	Sig. Diff.		

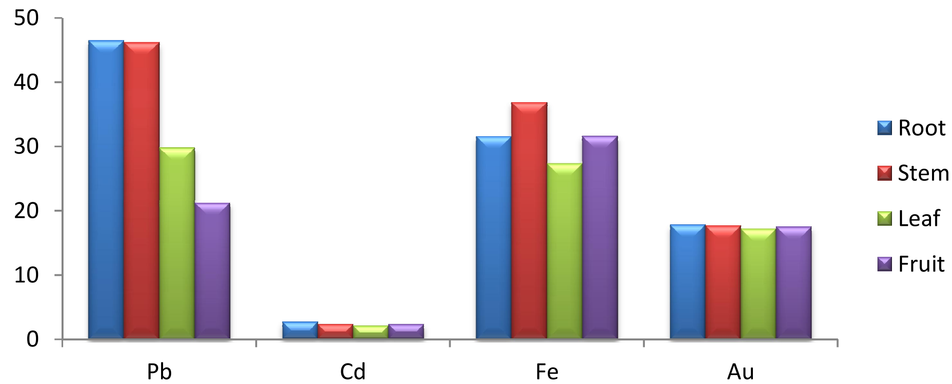

Fig. 1. Levels of heavy metals in mango plant parts during the study

Table 5. Translocation factors of metals in mango plant during the study

Metals	Conc. (mg/kg) in root	Conc. (mg/kg) in shoot	Translocation factor
Pb	46.48	32.39	0.70
Cd	2.68	2.23	0.83
Fe	31.56	31.91	1.00
Au	17.78	17.44	0.98

4. DISCUSSION

Generally metal levels in mango root, stem, leaves and fruits across sampling stations showed significant difference ($P<0.05$) with the mining areas having higher values than the control. This could be as a result of their direct association with the mining waste (soil) and water from which they absorb these metals [16]. Also, [17], investigated the relationship between soils and plants heavy metal concentrations in Nepal and they reported that the capability of heavy metal transfer to the plants was significantly increased by soils heavy metal concentrations though there are some other things such as bioavailability, speciation, etc, that also influence the soil–plant transfer factor. Pb was the highest occurring metal in all cases which could be owing to the fact that it is more abundant than any metal in the underlying rocks in that area [18]. [19] also obtained a similar result in their study on pollution indices of heavy metals and stated that Pb accumulates in bones and teeth, where it has a biological half-life of about 20 years during which it is released into the bloodstream where it then travels to target organs such as the brain, kidney.

Fruits are the most important part of mango plant to humans because they are directly consumed. The ripe fruits are sweet, emollient, laxative, cardiotonic, haemostatic and aphrodisiac [20]. The concentration of metals in mango fruit was a cause of concern because all of them exceeded the WHO and FAO maximum permissible limits which point out that mango fruits in the mining area are not fit for consumption. This is similar to the findings of [21] in his study on some selected fruits and vegetables in Enyigba Pb–Zn mine derelict, Nigeria where metal concentrations in fruits have a direct relationship with their availability in the soil.

The soil–plant transfer factor known as translocation factor (TF) is one of the important parameters used to estimate the possible accumulation of toxic elements. It is the transfer capability of metal from soil to various parts of the plant. Translocation factor is influenced by the bioavailability of metals which in turn is affected by metal concentration in the soil, its chemical forms and growth rate of different plants. Translocation factor of one (1) or close to it indicates that the plant translocate metals effectively from root to shoot. The translocation factors of all the heavy metals studied indicated fairly good movement of metals from the root to the shoot, closer to the findings of [22,23] in their studies on soil and metal content of some selected fruits in Sierra Leone where TF of mango was not less than 0.50 in any of the metals studied.

The variations in mean metal concentrations in mango plant parts (root, stem leaf and fruit) indicated that the root tends to have the highest values in most metals. Similar metal accumulation pattern of root > stem > leaf > fruit was observed by [20] in their study on accumulation of heavy metals by vegetables grown in mine wastes.

5. CONCLUSION

This study found out that generally metal concentration in mango plants from the mining area were higher compared to the control, indicating the environmental impact of gold mining activities in the area. Metal translocation factors were all high (> 0.5) which shows an efficient movement of metals from the root to the shoot in mango plant. Metal concentrations in mango fruits studied have exceeded the WHO and FAO standard and therefore considered unsafe for consumption which is a cause for worry because the inhabitants of these areas do consume these fruits without knowing the implications thereof.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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